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A STUDY
OF THE
CACHE CREEK SERIES, B.C.

M.B.B. CROCKFORD

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A STUDY

of

THE CACHE CREEK SERIES, B. C.

by

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UNIVERSITY OF ALBERTA

A Thesis
Submitted to the University of Alberta
in partial fulfilment of the re-
quirements for the degree of
MASTER OF SCIENCE.

Edmonton, Alberta April, 1935.

PLATE I

View of Cache creek looking east

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A STUDY OF THE CACHE CREEK SERIES, B. C.

CHAPTER I

INTRODUCTION

INTRODUCTORY REMARKS

As a result of their investigations in British Columbia in 1871, A. R. C. Selwyn[1] and James Richardson divided the rocks encountered into eight groups. Of these, the fourth and fifth were the Upper Cache Creek (Marble Canyon limestones) and the Lower Cache Creek groups respectively.

[1]Selwyn, A. R. C., Journal and Report on British Columbia: Geol. Surv., Can., Report of Progress 1871-72, p. 54.

The Upper Cache Creek group was first observed by Richardson between Clinton and Lillooet, and was assigned to the Eocene or Cretaceous on account of the presence of a Foraminifera which was later described by G. M. Dawson[2] as Loftusia columbiana.

[2]Dawson, G. M., Report on Explorations in the Southern Portion of British Columbia: Geol. Surv., Can., Report of Progress 1877-78, pt. B, p. 88.

The Lower Cache Creek group was encountered above Spences Bridge on Thompson river and the age was stated by Billings[3] as being between the base of the

[3]Billings, I. in Selwyn, A. R. C., loc. cit., p. 62.

Devonian and the summit of the Permian on the evidence of the contained fossils.

Later, in 1876, G. M. Dawson[4] found the

[4]Dawson, G. M., Report on Explorations in British Columbia: Geol. Surv., Can., Report of Progress 1876-77, pp. 54, 59.
Dawson, G. M., Report on Explorations in the Southern Portion of British Columbia: Geol. Surv., Can., Report of Progress 1877-78, pt. B, p. 89.

Foraminifera, Fusulina in the Lower Cache Creek group at Stuart lake. This form was also found in association with Loftusia of the Upper Cache Creek group of Marble canyon. These facts led Dawson[5] to consolidate

[5]Dawson, G. M., Report on Explorations in the Southern Portion of British Columbia: Geol. Surv., Can., Report of Progress 1877-78, pt. B, p. 169.
Dawson, G. M., Kamloops Map-sheet, British Columbia: Geol. Surv., Can., Annual Report 1896, pt. B, p. 38.

the two groups under the name of the Cache Creek series.

PREVIOUS WORK

The number of workers who have contributed to our knowledge of the Cache Creek series is so consid-

erable that no attempt will be made here to outline their findings. They, however, are given in detailed form in the next chapter. Special mention though should be made of Selwyn and Richardson, who followed the series up Fraser river and across to the Parsnip; of G. M. Dawson, who has contributed so much to our knowledge of the series, and who, in his explorations, found the series represented from the international boundary to the Yukon; of J. C. Gwillim, who recognized this series at Atlin, Tagish and Teslin lakes; of D. D. Cairnes, who found it in the Yukon; of C. Camsell, who noted extensive exposures at Takla lake; of R. A. Daly, who described their occurrence along the 49th parallel and also east of Kamloops, where he studied them in detail; and of C. E. Cairnes, who worked mainly in the Coquihalla area.

SCOPE OF THESIS

The writer aims to determine as accurately as possible the distribution of this series in British Columbia from the literature, to present the character and the stratigraphy of the rocks, to identify the fossils which he collected from these rocks, and to determine the faunal relationships through these identifi-

cations and through the determinations of fossils made by other workers. The economic aspects of the series are also considered.

ACKNOWLEDGEMENTS

The writer wishes to express his indebtedness to the following: Dr. J. A. Allan for kindly criticism and suggestions; Dr. P. S. Warren, under whose direction this thesis was prepared, for helpful suggestions and access to the literature used in its preparation; Dr. Warren encouraged the writer by his interest and enthusiasm to prosecute the search for fossil evidence regarding this series of rocks, and gave freely of his time in checking over the identifications which are noted later in this work; Mr. W. F. Palmer, who enabled the writer to visit the many exposures of these rocks in the vicinity of Kamloops, and who gave great assistance in the field; to Mr. McMorrin for accommodation for several days; and to Vera Crockford for assistance in collecting fossils.

CHAPTER II

CHARACTER AND DISTRIBUTION

CHARACTER

Selwyn's[6] description of the series in the re-

[6]Selwyn, A. R. C., loc. cit., pp. 60-61.

gion of Cache creek, where it was named, is as follows:

> "Upper Cache Creek group:-they consist of a great volume of bluish, dove-colored, and white limestones, often a good marble, interstratified with brown dolomitic limestone, red and green shale, and epidotic and chloritic rocks, with others which closely resemble rocks of the Quebec Group in the Eastern Townships of Canada.
>
> Lower Cache Creek group:-they consist of massive beds of sub-crystalline limestone, black, flinty shale in beds of from one to three or four inches thick, chloritic and epidotic rocks with serpentine and soapstone; there are also great thicknesses of crystalline dioritic rocks and porphyritic felsite--a brown, compact rock holding small crystals of pink feldspar."

Dawson[7] has also described the rocks in the

[7]Dawson, G. M., Kamloops Map-sheet, British Columbia: Geol. Surv., Can., Annual Report 1896, pt. B, p. 46.

same area, giving this generalized section in descending order:

1. Massive limestones (Marble Canyon limestones) with minor intercalations of volcanic rocks, argillites and cherty quartzites. At least 1000 feet seen in some single exposures.
   Total thickness at least-------3000 feet.

2. Volcanic materials and some limestones, with some argillites, cherty quartzites, etc.
Minimum thickness about---------2000 feet.

3. Cherty quartzites, argillites, volcanic materials, and serpentines with some limestone. The thickness of these beds or a part of them was roughly estimated in two places as between 4000 and 5000 feet.
Minimum thickness say----------4500 feet.

Total thickness----------9500 feet.

Dawson gives 9500 feet as a minimum thickness for the series, but was inclined to believe it exceeds 15, 000 feet.

The writer made a hurried trip through this area, and observed that marble was developed only in proximity to the granitic intrusions of Marble Canyon and the Marble mountains, and elsewhere limestone prevailed.

A noteworthy feature in the above section is a decrease in the amount of limestone from top to bottom of the series, as the limestone beds are fewer and thinner towards the bottom, in places being only a few feet in thickness.

In this area the only fossils found were Foraminifera and abundant crinoid stems.

Along the north side of South Thompson river,

from Kamloops east, Daly[8] gives the following pro-

[8]Daly, R. A., Golden to Kamloops: Geol. Surv., Can., Mem. 68, pp. 120-121.

visional section:

PLATE II

Contact of the Cache Creek limestone (left) and the Nicola (Triassic) traps (dark); Pleistocene white silts in foreground.

Uncomformable contact with Nicola series.

	Approximate thickness in feet.
1. Massive fossiliferous limestone, with cherty nodules and lenses	1,000
2. Grey argillite, sandstone, and quartzite, weathering brown	1,500
3. Massive sandstone and argillite, weathering grey	800
4. Massive fossiliferous limestone, with a 90-foot bed of volcanic ash and agglomerate in the middle	500

5.	Dark, cherty quartzite with interbeds of sandstone and basic volcanic rock	1,800
6.	Massive fossiliferous limestone	100
7.	Dark, cherty quartzite, with intercalated ash-beds	1,200
8.	Massive limestone	800
9.	Well bedded, black to dark grey, cherty quartzite with interbeds of massive basaltic ash and some flows of amygdaloidal olivine basalt	3,000
10.	Black cherty quartzite, dark siliceous argillite, and greywacke in alternating beds; one 8-foot bed of grey limestone	2,500
11.	Basaltic ash-beds, with interbeds of cherty quartzite	500
		13,700

Base concealed.

Daly suggests that members 4, 6 and 8 may be parts of member 1 repeated in outcrop, but the writer is inclined to believe from fossil evidence that this suggestion is not borne out. The limestones in this locality are extremely fossiliferous in some horizons and barren in others. Considerable time was spent in the study of this section, and no one fossil horizon was found to be repeated. Each horizon carries a predominating fossil: in member 1 a coral resembling Zaphrentis is very abundant in one horizon, and a very

large Productus in another; in member 4 there is a Derbya (?) horizon two feet thick; and in member 8 a small brachiopod resembling Martinia. These fossils were not found at any two places, in fact the only fossil common to these members was the coral.

On comparing Daly's section with Dawson's it will be noticed: (1) that the massive limestones have not been metamorphosed in the eastern area. These beds were traced northwest to North Thompson river, but in no place was marble found; (2) that Daly's section shows more argillite and quartzite, probably due to an approach to littoral conditions.

The limestones for the most part are tough, fine-grained, blue-grey in color, and on close examination are seen to be much fractured and crushed, the fractures being sealed with veinlets of silica and calcite. In some places crinoid columns are abundant--sometimes, so much so that the rock appears to be entirely composed of these remains. They rarely show any bedding planes. Faults are common, and the dips are mostly in the neighborhood of ninety degrees; consequently the structural relations are very difficult to interpret.

PLATE III

View of a small, tight faulted fold in member 1. Compare size with hat.

PLATE IV

View of fault in member 8.

The argillites are hard and dark-colored, varying from black to grey, and are often schistose. The quartzites are generally in thin bands only a few

inches thick, and are fine-grained, and greenish-grey in color. They commonly show small veinlets of white silica. They have probably been derived from silts or argillites, or from silica-rich solutions associated with vulcanism, which was prevalent at that time.

PLATE V

View of member 4; dark, volcanic rock in the foreground.

PLATE VI

View of vertically-dipping, thin-bedded quartzites along the North Thompson road, 7 miles north of Kamloops.

The volcanic materials consist of fine-grained diabases, much decomposed, agglomerates, tuffs and serpentines, the last being a characteristic feature of the lower part of the series, and have probably resulted from the decomposition of some highly basic rock.

The topography yielded by these rocks is variable, depending on the agents of erosion and the type of rock. In the interior of British Columbia, to which the writer's observations were confined, rainfall is scanty, winters are mild, and winds blow intermittently; therefore erosion takes place but slowly. The rocks are worn away chiefly in the spring when the snow melts, giving rise to torrential streams which carry heavy loads, thus aggrading their beds quickly. This results in numerous dry gullies and ravines, the sides of which are steep. The quartzites of the lower part of the series and the limestones of the upper part resist weathering better than the other rocks of the series. The quartzites form steep cliffs with talus slopes at the foot; the tilted limestones form rounded bluffs or mountains, depending on the thickness of the beds. Valleys have been worn in the incompetent rocks chiefly by ice during the Glacial period. In other parts of the province where the limestones are of sufficient thickness,

they form conspicuous hills or ridges owing to their greater resistance to erosive agencies. The limestone beds at lower elevations have been rounded off by glacial action.

DISTRIBUTION

This is probably the most widespread series of rocks in British Columbia, being found from the Pacific ocean to the Selkirk mountains, and from the southern to the northern boundaries of the province. It is also found in the Yukon and in Washington. Dawson[9] correlates

[9]Dawson, G. M., Kamloops Map-sheet, British Columbia: Geol. Surv., Can., Annual Report 1896, pt. B, pp. 48-49.
Diller, J. S., Geology of the Taylorville Region of California: Bull. Geol. Soc. Am., Vol. 3, pp. 372, 374-376.
King, C., Geology of the Fortieth Parallel, Vol. 1, p. 248.

them with rocks found in Oregon, California and Nevada on lithological and palaeontological grounds. In the Yukon[10]

[10]Cairnes, D. D., The Yukon-Alaska Boundary between Porcupine and Yukon Rivers: Geol. Surv., Can., Mem. 67, pp. 84-93.

the volcanics are lacking, so that the series is represented by about 3500 feet of limestones, conglomerates, slates and sandstones.

The occurrences of this series in British Columbia and adjacent areas are given below in tabular form. On account of the great number of references, this information is grouped according to areas in preference to outlining the observations of each worker. Also the sources of information regarding any particular exposure of these rocks are made readily available.

Abbreviations, noted below, have been used for most of the references in order to make the latter concise as possible. As the bulk of the data has been derived from the reports of the Geological Survey of Canada, few abbreviations are required.

DEFINITE AND PROBABLE OCCURRENCES OF THE CACHE CREEK SERIES

Note abbreviations:

R. P.--Report of Progress, Geological Survey, Canada.
A. R.--Annual Report, Geological Survey, Canada.
S. R.--Summary Report, Geological Survey, Canada.
Mem.---Memoir, Geological Survey, Canada.
G. B.--Guide Book issued by the Geological Survey of Canada.

LOCATION	REFERENCE	REMARKS
Region lying between the Bonaparte and Thompson rivers and Fraser river	1. Selwyn, A. R. C.: R. P. 1871-72, p.54. 2. Dawson, G. M.: R. P. 1877-78, pp. 88-96; map in pocket. 3. Dawson, G. M.: A R. 1896B, pp. 37-49, 79-112; map 556 (1895). 4. Drysdale, C. W.: S. R. 1912, p. 117.	The series is typically developed in this area. Thick beds of marble and limestone of the upper part of the series are extensively exposed in Marble Canyon and the Pavilion and Marble mountains. Dunbar places these rocks in the Permian.

LOCATION	REFERENCE	REMARKS
	5. Dunbar, C. O.: Trans. Roy. Soc. Canada, Third Series, Vol. XXVI, Section Iv, 1932, pp. 45-49.	
Lillooet to Anderson lake	1. Dawson, G. M.: Geol. Surv., Canada, map 556 (1895). 2. Camsell, C.: S. R. 1912, p. 112. 3. Camsell, C.: S. R. 1917, p. 15.	Only the lower part of the series is exposed here.
Bridge river	1. Camsell, C.: S. R. 1911, p. 112. 2. Drysdale, C. W.: S. R. 1915, p. 79; map 1610. 3. McCann, W. S.: Mem. 130, p. 23; map 1882 (1922). 4. Cockfield, W. E.: S. R. 1931A, p. 47.	McCann correlates the Bridge river series with the lower part of the Cache Creek series. Cockfield accepts this correlation.
Churn creek	MacKenzie, J. D.: S. R. 1920A, pp. 72-73; map opp. p. 70.	The Bridge River series is considered to extend into this area.
North Bend	1. Selwyn, A. R. C.: R. P. 1871-72, p. 62. 2. Dawson, G. M.: A. R. 1894, p. 38, 42-44. 3. Drysdale, C. W.: G. B. # 8, map opp. p. 264 (1913).	The Anderson River and Boston Bar groups found here are included in the Cache Creek series, as Dawson was unable to separate them from it.

LOCATION	REFERENCE	REMARKS
Coquihalla area	1. Dawson, G. M.: R. P. 1877-78, pp. 71-72; map in pocket. 2. Camsell, C.: S. R. 1911, p. 109. 3. Bateman, A. M.: S. R. 1911, p. 126. 4. Drysdale, C. W.: G. B. # 8, map opp. p. 264 (1913) 5. Camsell, C.: S. R. 1919B, p. 32. 6. Cairnes, C. E.: S. R. 1920A, p. 26. 7. Cairnes, C. E.: Mem. 139, p. 33; map 1988 (1924) 8. Cairnes, C. E.: S. R. 1929A, p. 147; map p. 145.	The lower part of the series is exposed here, and, according to Cairnes[7] consists exxentially of greenstone (augite andesite), chert and limestone bands. The Boston Bar and Anderson River groups extend into this area, as well as the Siwash series of Bateman, which he considered the equivalent of the Cache Creek series.
Harrison lake	1. Drysdale, C. W.,: G. B. # 8, map opp. p. 264 (1913). 2. Crickmay, C. H.: Geol. Surv., Canada Museum Bulletin # 63 pp. 35, 36, 38 (1930).	Crickmay notes argillites and limestones, the latter containing what he considered to be Pennsylvanian fossils.
Southern Vancouver island	1. Dawson, G. M.: R. P. 1876-77 pp. 55, 88, 101. 2. Clapp, C. H.: Mem. 13, pp. 151, 152 (1912). 3. Clapp, C. H.: Mem. 96, pp. 92-93; maps 1192, 1194 (1917).	Dawson[1] first pointed out the relations of the series at Stuart lake to the rocks found here. Clapp[2] says the Leech River formation is a lower part of the Cache Creek series found on the mainland, though the limestones are lacking here. He also correlates the Malahat formation with the Cache Creek series on lithology.

LOCATION	REFERENCE	REMARKS
Mount Mark and Horne lake	1. Richardson, J.: R. P. 1872-73, p. 54. 2. McConnell, R. G.: Mem. 58, p. 19 (1914).	Billings[1] said the rocks were Carboniferous or Permian. McConnell[2] correlates them with the Marble Bay formation, which is Triassic.
Buttle lake	1. Gunning, H. C.: S. R. 1930A, p. 59. 2. Fritz, M. A.: Transactions of Royal Society of Canada, Vol. XXVI, Section IV, 1932, p. 93, 94.	Bryozoans collected by Gunning[1] and described by Fritz[2] show striking resemblances with those of the Permian from Timor and affinities with those of the Salt range.
Abbotsford	Daly, R. A.: Mem. 38, pp. 504, 515, maps 16 and 17 (1912).	The fossiliferous Chilliwack series is said to be Upper Carboniferous by Girty and equivalent to the Nosoni formation of California. Daly correlates it with the Hozomeen and Cache Creek series.
Skagit river	1. Camsell, C.: S. R. 1911, p. 118. 2. Daly, R. A.: Mem. 38, pp. 502, 504; maps 14 and 15 (1912). 3. Cairnes, C. E.: S. R. 1931A, p. 51; map opp. p. 46.	The Hozomeen series is correlated with the Cache Creek series (as described by Dawson) by Daly and Cairnes on stratigraphic and lithological resemblances.
Princeton	1. Dawson, G. M.: R. P. 1877-78, pp. 83, 87. 2. Camsell, C.: S. R. 1906, p. 47. 3. Camsell, C.: G. B. # 9, maps opp. pp. 106 and 126 (1913).	The rocks have limestone associated with the ores and are referred to the Cache Creek series by Dawson.

LOCATION	REFERENCE	REMARKS
Keremeos	1. Dawson, G. M.: R. P. 1877-78, p. 87 map in pocket. 2. Camsell, C.: G. B. # 9, map opp. p. 106 (1913). 3. Smith, S.: Journal of Palaeontology, Vol. 9, # 1, p. 30 (1935).	Cairnes correlates these rocks with Daly's Hozomeen series of the international boundary further south. Corals identified by Smith are considered Permian.
Osoyoos and Rock creek	Camsell, C.: G. B. # 9, map opp. p. 106 (1913).	Rocks are doubtfully referred to the Cache Creek series.
Beaverdell	Reinecke, L.: Mem. 79, p. 29 (1915).	Occurrences of metamorphosed limestone correlated with the Cache Creek series.
Greenwood and Phoenix	1. Brock, R. W.: S. R. 1902, p. 96. 2. LeRoy, O. E.: Mem. 21, pp. 30-34 (1912) 3. LeRoy, O. E.: Mem. 19, p. 17 (1913).	The Atwood series of Brock resembles the Cache Creek series. The Atwood series is split up into the Brooklyn and Rawhide formation.
Grand Forks and Rossland	1. Daly, R. A.: Mem. 38, p. 382; maps 9 and 10 (1912). 2. Drysdale, C. W.: Mem. 77, pp. 25, 199 (1915).	The Mount Roberts formation of Rossland contains Carboniferous fossils and is probably equivalent to the Atwood series. Drysdale correlates the Brooklyn and Knob hill formations at Phoenix and the Mount Roberts formation with the Cache Creek series

LOCATION	REFERENCE	REMARKS
North Fork of the Kettle river	1. Brock, R. W.: A. R. 1900, pp. 71-74. 2. Daly, R. A.: Mem. 38, pp. 382-383; maps 9 and 10 (1912). 3. Drysdale, C. W.: Mem. 56, p. 53; map 1286 (1915).	Brock reported rocks resembling the Cache Creek series along this river. Drysdale correlates the Gloucester formation of the Franklin district with the Cache Creek series, and probably with the Atwood series which Daly says resembles the Mount Roberts formation of Rossland.
Pend d'Oreille river	1. Brock, R. W. and McConnell, R. G. map 792 (1901). 2. Daly, R. A.: Mem. 38, p. 276; map 7 (1912). 3. LeRoy, O. E.: G. B. # 9, p. 64 (1915).	Daly correlates the Pend d'Oreille group with the Cache Creek series on lithological grounds. LeRoy considers the group to be a metamorphosed phase of the Triassic Slocan series. Brock and McConnell give it a Lower Cambrian age.
Northern Okanagan lake	Cairnes, C. E.: S. R. 1931A, p. 68.	The lower part of the Cache Creek series found here.
Kamloops	1. Dawson, G. M.: R. P. 1877-78, p. 79-80; map in pocket. 2. Dawson, G. M.: Kamloops Map Sheet # 556 (1895). 3. Dawson, G. M.: A. R. 1896, p. 103-107B. 4. Drysdale, C. W.: G. B. # 8, p. 240; map opp. p. 244 (1913). 5. Daly, R. A.: Mem. 68, pp. 117-122; map 1446 (1915).	The series is represented here, on both sides of the North and South Thompson rivers, and particularly well on the north side of the latter, for which Daly gives a section. The massive limestones here have yielded diagnostic fossils. Dawson includes the Campbell Creek beds, which are found here on the south side of the river, in the Cache Creek series.

LOCATION	REFERENCE	REMARKS
Kamloops (continued)	6. Miller, A. K. and Warren, P. S.: American Journal of Science Vol. XXVI, September 1933, p. 295-299.	
Clearwater river	Walker, J. F.: S. R. 1930A, p. 131.	The Lemieux Creek formation contains Brachiopods and Carboniferous Bryozoa. Rocks are probably Cache Creek.
Chilcotin river to Soda creek	1. Dawson, G. M.: R. P. 1876-77, map opp. p. 17. 2. Reinecke, L.: Mem. 130, p. 8 (1920). 3. Cockfield, W. E.: S. R. 1931A p. 59.	The lower part of the Cache Creek series is exposed along the Fraser river. Dawson also noted it at Tatla lake and along the Chilcotin.
Quesnel Forks	Cockfield, W. E.: and Walker, J. F.: S. R. 1932A, pp. 78-80.	Lower part of the series here.
Barkerville area	1. Bowman, A.: A. R. 1877-88, Vol. 3, Part I, pp. 20-22; map C, 1887. 2. Uglow, W. L.: S. R. 1922A, p. 84. 3. Johnston, W. A. and Uglow, W. L.: Mem. 149, p. 23; map 2046 (1926) 4. Johnston, W. A. and Uglow, W. L.: S. R. 1932AI, pp. 6-7.	The lower part of the series is called the Bear River beds by Bowman and the Slide Mountain series by Johnston and Uglow. Carboniferous fossils are reported by Uglow[2] from the Bear River beds on Slide mountain.
Quesnel to Fort Fraser	1. Dawson, G. M.: R. P. 1876-77, p. 55; map opp. p. 16. 2. Reinecke, L.: Mem. 118, p. 8 (1920).	The lower part of the series is well exposed over a considerable area.

LOCATION	REFERENCE	REMARKS
Ootsa lake	Brock, R. W.: S. R. 1920 A, p. 85; map on p. 82.	The outcrops on the accompanying map are located approximately as Brock has not stated definitely where he found them.
Stuart lake	1. Selwyn, A. R. C.: R. P. 1875-76, pp. 77-78, map at front. 2. Dawson, G. M.: R. P. 1876-77, p. 56. 3. Camsell, C.: S. R. 1915, p. 72: map 1607. 4. Camsell, C.: S. R. 1917, p. 15.	Fusulina found by Dawson in the limestones here, thus linking the rocks with those of Marble Canyon.
Babine lake	Dawson, G. M.: R. P. 1879-80, p. 106; sheet I.	Small exposure.
Salmon river	Selwyn, A. R. C.: R. P. 1875-76, p. 79.	Small exposure of reddish weathering flinty shales.
McLeod lake and Parsnip river	1. Selwyn, A. R. C.: R. P. 1875-76, pp. 79, 80. 2. Dawson, G. M.: R. P. 1879-80, p. 108; map B, sheet II.	Massive, fossiliferous limestone, with schists, argillites and cherty quartzites.
Mount Selwyn and Fossil Point	Selwyn, A. R. C.: R. P. 1875-76, p. 80; map opp. p. 1.	Limestones containing crinoid stems and imperfectly preserved fossils found at Fossil Point.
Takla lake and Omineca river	1. McConnell, R. G.: A. R. 1894, p. 25C. 2. Camsell, C.: S. R. 1915, p. 73; map 1607.	The same rocks found here as at Stuart lake.

LOCATION	REFERENCE	REMARKS
Finlay, Ingenika and Mesilinka rivers	Dalmadge, V.: S. R. 1927A, p. 27, map 2156.	The rocks are similar to those found by Camsell at Takla lake.
Dease and Frances rivers	Dawson, G. M.: A. R. 1887B (second edition) pp. 30, 91, 102; map 3, sheet II.	Limestones contain Fusulina.
Dease lake	1. Dawson, G. M.: A. R. 1887B (second edition), pp. 67, 75; map 3, sheet I. 2. Kerr, F. A.: S. R. 1925A, p. 81; map 2104. 3. Kindle, E. M.: Trans. Royal Soc., Canada, Vol. XX, 1926, pp. 109-111.	Series called here the Dease series by Kerr, which he estimates to be about 10,000 feet thick. Dawson found Fusulina in the limestones; Kerr found among other fossils, Leptodus (Lyttonia) which is a distinctly Permian genus.
Clearwater (Chutine) river	1. Dawson, G. M.: A. R. 1887, p. 53. 2. Kerr, F. A.: S. R. 1928A, p. 19; map opp. p. 12.	Lower part of the series found here.
Lower Stikine river	Kerr, F. A.: S. R. 1928A. p. 19: map opp. p. 12.	Lower part of the series found here.
Iskut river	Kerr, F. A.: S. R. 1929A, p. 50; map on p. 32.	Lower part of the series only.
Tagish, Atlin and Teslin lakes	1. Dawson, G. M.: A. R. 1887, pp. 169-170. 2. Gwillim, J. C.: A. R. 1899, p. 16-18; map 742.	Dawson reports argillaceous schists and calc-schists along with massive limestone and marble. The limestone was found to con-

LOCATION	REFERENCE	REMARKS
Tagish, Atlin and Teslin lakes (continued)	3. Cairnes, D. D.: Mem. 37, p. 54; map 1283 (1913). 4. Cockfield, W. E.: S. R. 1925A, p. 27; map 2097.	tain Fusulina on Windy Arm of Tagish lake. The massive limestones of the upper part of the series were called the Gold series by Gwillim and the Braeburn limestone by Cairnes.
Upper Taku river	Cockfield, W. E.: S. R. 1925A, p. 27; map 2097.	Lower part of the series.
Lower Taku river	1. Kerr, F. A.: S. R. 1930A, p. 51; map 2290. 2. Kerr, F. A.: S. R. 1932A II, p. 17; fig 3, p. 6.	Kerr found the same rocks here as at Dease lake.
Rainy Hollow	1. Wright, C. W.: U. S. G. S. Bull. 236, p. 16 (1904). 2. McConnell, R. G.: S. R. 1913, p. 30.	Wright collected fossils immediately south of this area which Girty believes to be Carboniferous, and probably Mississippian. Referred to the Cache Creek series with some doubt.
Prince Rupert and adjacent islands	1. Wright, F. E. and C. W.: U. S. G. S. Bull. 347, pp. 52-57; plate II (1908). 2. McConnell, R. G.: S. R. 1912, p. 60. 3. McConnell, R. G.: G. B. # 10, pp. 17-18; map opp. p. 22 (1913). 4. Dalmadge, V.: S. R. 1922A, p. 12: map opp. p. 12; figs. 1 and 2.	The Prince Rupert formation is tentatively referred to the Cache Creek series. McConnell[2] says it is equivalent to the Cache Creek. Dalmadge says it is either Triassic or Upper Palaeozoic. To the north in the Ketchikan and Wrangell districts F. E. and C. W. Wright obtained fos-

LOCATION	REFERENCE	REMARKS
Prince Rupert and adjacent islands (continued)	5. Hanson, G.: S. R. 1924A, p. 40. 6. Geological Survey of Canada, Prince Rupert sheet, map 2286 (1933).	sils which Girty gave a Gschelian age. The fauna resembles that found near Kamloops, and as he also assigned it to the Gschelian, the Prince Rupert formation, or at least part of it, is placed as equivalent to the Cache Creek series.
Zymoetz river	1. Dawson, G. M.: R. P. 1879-80, p. 102; map B, sheet I. 2. Hanson, G.: S. R. 1925A, p. 103; map 2098.	Hanson obtained fossils which Kindle identified as belonging to the Alaskan fauna.
Lewes and Nordenskiold rivers (Yukon)	1. Dawson, G. M.: A. R. 1887, p. 169. 2. Cairnes, D. D.: Mem. 5, pp. 28-29; map 1103, 1104 (1910).	The Braeburn limestones found here are assigned to the upper part of the Cache Creek series; fossils are indefinite.
Nation river (Yukon)	Cairnes, D. D.: Mem. 67, pp. 102-103, maps 1443, 1444 (1914).	The Nation River and Racquet groups of this area are probably included in the Braeburn limestones, which are found further south. These groups take in the Pennsylvanian and possibly the Permian and Mississippian. Fossils collected here are assigned to the Gschelian.
Pelly river Hoole canyon	Dawson, G. M.: A. R. 1887, p. 123B; map 3, sheet 2.	"The rocks resemble precisely the Cache Creek series of Southern B. C."

LOCATION	REFERENCE	REMARKS
Queen Charlotte islands	1. Dawson, G. M.: R. P. 1879-80, pp. 45, 57; map at front. 2. Geological Survey of Canada, Prince Rupert Sheet, map 2286 (1933).	Rocks found by Dawson at Werner and Hutton inlets resemble those of the interior of British Columbia and also of southern Vancouver island, but cannot be separated from overlying Triassic beds.
Northern Washington	Smith, G. O. and Calkins, F. C.: U. S. G. S. Bull. 235, pp. 21-24; map opp. p. 12 (1904).	Rocks found here are correlated with the Cache Creek series of British Columbia. They consist of slate, quartzite, schist, greenstone and beds of limestone.

CHAPTER III

STRATIGRAPHY AND PALAEONTOLOGY

STRATIGRAPHY

The (now considered Permian) Cache Creek series includes about 10,000 to 15,000 feet of limestones (and marbles), argillites, quartzites and volcanics. The exact succession, excepting for the provisional one of Daly, has not been worked out, due to the extreme folding and faulting suffered by the rocks, and also to the varying degrees of metamorphism to which the rocks have been subjected in various parts of the province. Metamorphism would make the same member difficult of recognition in different regions.

The upper and lower limits of the series as defined by Dawson are not known definitely. The base is concealed in almost every place. In the Ketchikan and Wrangell district the Lower Carboniferous is separated from the Upper Carboniferous (considered Permian by the writer) by an apparent unconformity. In the Dease lake area the Permian limestones cannot be separated from the associated rocks below, which are considered to be Ordovician. The upper limit of the series is unconformable with the overlying rocks in every region where they have been studied. The limits will probably vary, as

will the thickness, as periods of erosion preceded and succeeded deposition.

Until recently the age of the series has been given as Carboniferous, that age being assigned by Dawson, though he stated that Permian and Devonian strata, particularly the latter, may be included. He based his conclusions on the presence of Fusulina, though that genus is not confined to the Carboniferous. The presence of the Permian had been suggested, but definite evidence was lacking, the principal fossils found being non-diagnostic corals and brachiopods. These, except for a few genera, are not satisfactory for differentiating the Carboniferous and Permian as species are common to both systems. Ammonites are the only common, reliable index fossils, but these had not been found until quite recently by the writer. Also fossil assemblages are rare in these rocks, and the remains found are generally in a poor state of preservation or are new species unfit for correlation purposes.

The exact horizons represented in the series were long in doubt. An initial determination was made when Selwyn[11] obtained a small collection of imperfectly

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[11] Selwyn, A. R. C., loc. cit., pp. 61-62.

preserved fossils near Spences Bridge; in it Billings recognized the following genera: Rhynchonella, Spirifer, Cyrtina, Myalina and Euomphalus. They were stated to indicate a horizon between the base of the Devonian and the summit of the Permian. A somewhat similar collection was made by Richardson[12] at Mount Mark and Horne lake on

[12]Richardson, J., Report on the Coal Fields of Vancouver and Queen Charlotte Islands: Geol. Surv., Can., Report of Progress 1872-73, p. 54.

Vancouver island. It was also examined by Billings, who stated it represented the Carboniferous or Permian, most likely the former. In 1906 R. W. Brock[13] collected

[13]Drysdale, C. W., Geology and Ore Deposits of Rossland, B. C.: Geol. Surv., Can., Mem. 67, pp. 84-93.

fossils from O. K. mountain at Rossland from the Mount Roberts formation. These were determined by Ami as:

Zaphrentis sp.
Stenopora or Rhombopora sp.
Productus semireticulatus
Productus sp.
Martinia sp.
Spirifer sp. cf. Spirifer cameratus.

Ami ascribed the collection to the Upper Carboniferous. D. D. Cairnes [14] made several collections in the White

[14]Cairnes, D. D., Upper White River District, Yukon: Geol. Surv., Can., Mem. 50, pp. 75-83.

River district of the Yukon. These were submitted to Girty, who was inclined to place their age as Gschelian or uppermost Carboniferous. A partial list of his determinations is as follows:

Zaphrentis sp.
Crinoid stems
Rhombopora sp.
Fenestella sp.
Polypora sp.
Derbya sp.
Productus sp.
Camarophoria sp.
Spirifer cameratus Tsch. non Morton
Squamularia aff. perplexa
Aviculipecten sp.
Orthoceras sp.

He stated these fossils resembled the Russian rather than the American facies. R. A. Daly[15] made a somewhat similar

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[15]Daly, R. A., loc. cit. pp. 121-122.

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though smaller collection near Kamloops on the South Thompson river in 1911-12. Girty to whom it was submitted, reported the following genera and species:

Endothyra sp.
Lophophyllum profundum var. sauridens
Crinoid stems.
Fistulipora sp.
Phyllopora? sp.
Camarophoria mutabilis
Camarophoria sella
Chonetes sp.
Productus cora Tsch. non D'Orb.
Productus sp.
Spirifer? sp. resembling Spiriferina simensis
Spiriferella arctica
Squamularia lineata Tsch. non Martin

Girty believed this fauna to represent a Gschelian rather than a Permian horizon. Although no fossils have been found in the Prince Rupert area, many collections have been obtained by members of the United States Geological Survey from the islands to the north. On the Keku islands immediately north of Kuiu island, F. E. and C. W. Wright[16] obtained the following fossils, as determined

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16Wright, F. E. and C. W., The Ketchikan and Wrangell Mining Districts, Alaska: U. S. G. S. Bull. 347, pp. 52-27.

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by Girty:

Fusulina cf. longissima
Rhombopora sp.
Stenopora sp.
Derbya sp.
Meekella sp.
Chonetes sp.
Camarophoria cf. purdoni Davidson
Camarophoria aff. superestes
Spirifer arcticus
Spirifer cameratus Tsch. non Morton
Squamularia sp.

These were stated to be Gschelian, as were other collections made on neighboring islands. As these rocks extend south to Prince Rupert and west to the Stikine river, they serve to link up those areas.

More definite evidence as to the age of this

series was obtained by F. A. Kerr[17] from the Dease series

[17]Kerr, F. A., Dease Lake Area, Cassiar District, B. C.: Geol. Surv., Can., Sum. Rept. 1925, pt. A, p. 31.
Kindle, E. M., The Occurrence of the Genus Leptodus in the Anthracolithic Fauna of British Columbia: Trans. Royal Soc., Can., Vol. 20, 1926, pp. 109-111.

at Dease lake. There he found the following fossils, which were reported on by E. M. Kindle:

Fusulina sp.
Amblysiphonella sp.
Crinoid stems
Bryozoa (fragments)
Productus sp.
Leptodus (Lyttonia) cf. tenuis
Spirifer cf. cameratus
Eumetria? sp.
Athyris sp.
Spirigerella sp.

Of the general aspect of the collection Kindle says, "This fauna----------is more comparable with the Salt Range fauna of India than with anything else known to me". He places the Leptodus fauna of the Dease Lake district in the early Permian or Artinskian.

In 1930, H. C. Gunning[18] collected spirifers,

[18]Gunning, H. C., Buttle Lake Map Area, Vancouver Island: Geol. Surv., Can., Sum. Rept. 1930, pt. A, p. 59.

bryozoans and crinoid stems in the Buttle lake area of Vancouver island. The bryozoans were described by

Madeleine A. Fritz[19] who assigned them to the Permian.

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[19]Fritz, M. A., Permian Bryozoa from Vancouver Island: Trans. Royal Soc., Can., Vol. 26, Section 4, 1932, pp. 93-94.

She recognized seventeen species, ten of which were new, and four of the other seven had been described previously by Bassler from the Island of Timor. The following is a list of the bryozoa:

Ulrichotrypa prolifica sp. nov.
Rhombopora porifera sp. nov.
Streblotrypa pulchra sp. nov.
Claustrypa spinosa sp. nov.
Fenestella basleoensis Bassler
Fenestella parviuscula Bassler
Fenestella cf. pulchradoralis Bassler
Polypora consanguinea Bassler
Polypora vancouverensis sp. nov.
Polypora elongata sp. nov.
Polypora megastoma Koninck
Polypora sykesi Koninck
?Thamniscus unilateralis sp. nov.
Phyllopora cf. haimeana Koninck
Acanthocladia multipora sp. nov.
Pinnatopora grandis sp. nov.
Goniocladia intermedia sp. nov.

Fritz states that the bryozoa show affinities also with those of the Salt Range of India.

Later, in 1932, the writer made a collection on the South Thompson river, east of Kamloops, presumably at the same locality where Daly collected. In the collection were ammonites, which were determined by

A. K. Miller and P. S. Warren[20], and which proved to

[20]Miller, A. K. and Warren, P. S., A Propinacoceras from North America: Am. Jour. Sci., Vol. 26, Sept. 1933, pp. 295-299.

belong to the Permian genera, Waagenoceras, Agathiceras, Thalassoceras, and Propinacoceras. Only the last named genus was in a sufficient state of preservation to be thoroughly studied and is described by them as Propinacoceras americanum as it is the first of that genus to be found in America being previously confined to the Tethys area. The strata containing it are said to be "almost certainly Middle Permian". These fossils came from the top of the series (member 1 of Daly), close to the contact with the Triassic-Jurrasic Nicola series, and consequently places the upper limit of the series, in this area at least, in the Middle Permian. In the summer of 1934, the writer spent several weeks in this same area, and obtained a better collection of ammonites, but at the time of writing it has not been diagnosed, excert to confirm previous findings.

Also in 1932, C. O. Dunbar[21] restudied and re-

[21]Dunbar, C. O. Neoschwagerina in the Permian faunas of British Columbia: Trans. Royal Soc., Can., Vol. 26, Third Series, Section 4, pp. 45-48, 1932.

described Loftusia columbiana Dawson. This, he found, belongs to the genus Neoschwagerina, a genus practically confined to the Orient, and a characteristic Permian fossil, in some of the fusilina-limestones there. Conclusions based on a comparison of this fossil with other Neoschwagerinids lead Dunbar to suggest a Lower or Middle Permian age to the Marble Canyon limestones. This estimate agrees with the findings made by Miller and Warren.

Further evidence of Permian age was obtained in the finding of corals near Keremeos by H. S. Bostock. They were studied by Stanley Smith[22] of Bristol, England,

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22Smith, S., Two Anthracolithic Corals from British Columbia and Related Species from the Tethys: Journal of Palaeontology, Vol. 9, No. 1, p. 30, 1935.

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who identified them as belonging to the genera Waagenophyllum and Caninia. The former he describes under the name Waagenophyllum columbicum, and states that it indicates either an Upper Carboniferous or more probably a Permian age for the containing strata; the latter has too great a vertical range to be of diagnostic value. He states that these corals show an unmistakable affinity with the Anthracolithic corals of the Tethys.

An examination of the fauna collected from such widely separated localities as White river, Dease lake, Keku islands, Buttle lake, Rossland and Kamloops, shows an unmistakable relationship; for similar genera or species of bryozoa, and brachiopods are common to nearly all. Rhombopora is common to the faunas of White river, Keku islands and Buttle lake; "Spirifer cameratus" is another species which is found in practically all. Thus the fauna of one locality is related to that of another by comparable species, so that there can be but little doubt that the containing rocks are of the same series. This is further shown by the occurrence of these remains in limestones which are associated with volcanics, argillites and quartzites.

In a few of the areas cited above, the rocks are ascribed to the Gschelian, as definitely characteristic fossils are lacking. However, the upper part of the Gschelian, the Schwagerina-Kalk, is now placed in the lowermost Permian by some writers[23], and, as the fauna

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[23]Schuchert, C., Review of the Late Palaeozoic Formations and Faunas, with Special Reference to the Ice-age of Middle Permian Time: Geol. Soc., Am., Vol. 39, Sept. 1928, pp. 801, 808.

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of the Cache Creek series has been shown to be younger than the Gschelian, it would appear that the limestones

of the Yukon, Ketchikan and Prince Rupert districts and Rossland are Permian also.

PALAEONTOLOGY

A study of the fossils collected by the writer has been made with the object of comparing them with those of other known Permian faunas. These fossils were found in association with the ammonites mentioned in the preceding pages, and were contained in an impure, glauconitic limestone bed, weathering a rusty brown. The bed is exposed in only a very small area in a dry gully washed into the Pleistocene white silts, and within a few hundred feet of the contact with the Nicola series. The rock is much fractured, very hard, and the fossils so well incorporated in it that good specimens are scarce and difficult to free from the matrix.

PLATE VII

View showing the location of the fossil bed (marked "X").

PLATE VIII

Closer view of the bed.

PLATE IX

Close-up view of the bed.

Of the thirty-five or more different species of corals, brachiopods, pelecypods, gastropods, etc., only twelve could be determined specifically, or affinities shown with known species. These are given below.

Phylum MOLLUSCOIDEA Milne Edwards
Class BRACHIOPODA Dumeril
Order Protremata Beecher
Superfamily Strophomenacea Schuchert
Family Strophmenidae King
Subfamily Orthotetinae Waagen
Genus Streptorhynchus King

Streptorhynchus pelargonatus Schlotheim

1816. Terebratula pelargonatus Schlotheim, Denkschr. Bayer. Akad. Wissen. Munchen, Vol. 6, p. 28, Pl. 8, figs. 21-24.
1882. Streptorhynchus pelargonatus Waagen, Salt Range Fossils, Palaeontologica Indica, Vol. 1, Productus Limestone Fossils, Part 4 (fas. 3), p. 579, Pl. 50, figs. 3, 4, 5, 7.
1902. Streptorhynchus pelargonatus Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Mem. Comite Geol., Vol. 16, No. 2, p. 576, Pl. 26, figs. 6, 7.
1931. Streptorhynchus pelargonatus Grabau, Permian of Mongolia, p. 243, Pl. 24, figs. 2a-e.

The identification is based on the ventral valves of two specimens. They are identical with those described by Tschernyschew from the Urals, and also with those of Grabau from the Jisu Honguer limestone of Mongolia, even to having secondary and tertiary striations. They differ from those of the Productus limestone in having the beaks slightly more incurved, but Waagen

states that the outline is variable in his specimens, so that these are no doubt the same species. They are also slightly larger than those from the Productus limestone.

Family Productidae Gray

A number of brachiopods of the above family were collected, but are either new species or are so poorly preserved as to prohibit identification. Several genera such as Dictyoclostus, Linoproductus and Productus are believed to be present.

Superfamily Pentameracea Schuchert
Family Pentameridae McCoy
Genus Seminula McCoy
Subgenus Camarophoria King

Camarophoria cf. applanata Tschernyschew

1902. Camarophoria applanata Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Mem. Comite Geol., Vol. 16, No. 2, pp. 497-499; Pl. 46, fig. 1.

The specimens are referred to the above species with some doubt. The general shape and size are ~~slightly~~ comparable, though those from the Cache Creek series are slightly more inflated. Tschernyschew gives a maximum of seven plications to the median sinus; the Cache Creek species show eight or ten.

Camarophoria globosa Tschernyschew

1902. Camarophoria globosa Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Mem. Comite Geol. Vol. 16, No. 2, p. 495, Pl. 46, figs. 2, 3.

The specimens from the Cache Creek series correspond in every way to the above species from the Schwagerina-Kalk of the Urals. Each has four plications in the sinus and is globose. In the specimens from the Urals, the beak of the ventral valve curves over that of the dorsal valve. As the beaks are missing from those from the Cache Creek series, this latter can only be inferred from the size and position of the beak of the dorsal valve and from the shape of the ventral valve.

Camarophoria karpinskii Tschernyschew

1902. Camarophoria karpinskii Tschernyschew, Die obercarbonischen Brachiopoden d. Ural un d. Timan, Mem. Comite' Geol., Vol. 16, No. 2. p. 496, Pl. 60, figs. 2, 3.

Both specimens from the Cache Creek series and the Schwagerina-Kalk are subglobose, and the plications in the sinus start with two and come off in pairs but do not bifurcate.

Camarophoria mutabilis Tschernyschew

1902. Camarophoria mutabilis Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Vol. 16, No. 2, pp. 491-494, Pl. 45, figs. 1-15; Pl. 46, fig. 14.
1915. Camarophoria mutabilis, Girty, G. H. in Daly R. A., Golden to Kamloops, Geol. Surv. Can., Mem. 68, p. 121.
1931. Camarophoria mutabilis, Grabau, Permian of Mongolia, pp. 211-214, Pl. 4, figs. 7a-e; Pl. 5, figs. 1a-e, 2a-e.

This is doubtless the same species collected by Daly and identified by Girty as the above, as it

corresponds in every way to Tschernyschew's species from the Urals. Grabau also reports its occurrence in the Jisu Honguer limestone of Mongolia, but his specimens are either young or dwarfed.

Camarophoria cf. plicata Tschernyschew

1902. Camarophoria plicata Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Vol. 16, No. 2, pp. 502-503, Pl. 50, figs. 17, 18.

This specimen is poorly preserved, but seems to conform in shape and size to the above. It has seven plications on the fold as has that from the Urals, but the lateral plications are exfoliated so the specimen is referred to the above with reservations.

Order Telotremata Beecher
Superfamily Spiriferacea Waagen
Family Spiriferidae King
Subfamily Spiriferinae novum
Genus Spirifer Sowerby

Spirifer interplicatus var. bashkirica Tschernyschew

1892. Spirifer interplicatus Rothpletz, Die Perm-Trias. und Jura-Formation auf Timor und Rotti, Palaeontographica, Bd. 39, p. 78, Taf. 9, fig. 6.
1902. Spirifer interplicatus var. bashkirica Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Mem. Comité Geol., Vol. 2, No. 2, p. 540, Pl. 6, figs. 1-4.

The specimen from the Cache Creek series agrees with that of Tschernyschew's in shape and number of plications. It is, however, larger and the valve more curved, which points to a further development from the type i. e. it is a later form. The character of the

delthyrium cannot be determined.

Spirifer moosakhailensis Davidson

1862. Spirifer moosakhailensis Davidson, On Some Carboniferous Brachiopoda Collected in India, etc., Quart. Journ. Geol. Soc. London, Vol. 18, p. 28, Pl. 2, fig. 2.
1897. Spirifer musakheylensis Diener, Himalayan Fossils, Palaeontologica Indica, Series 15, Vol. 1, Part 4, pp. 35-40, Pl. 3, figs. 3, 4; Pl. 4, figs. 1, 2.
1899. Spirifer musakheylensis Diener, Himalayan Fossils, Palaeontologica Indica, Series 15, Vol. 1, Part 2, pp. 63, 64, Pl. 5, figs. 3-7.
1931. Spirifer moosakhailensis Grabau, Permian of Mongolia, p. 168, Pl. 23, figs. 5, 6, 7, 8.

These specimens do not show the full growth of shell so the marginal plicae cannot be seen; also the concentric lamellar structure is merely indicated as the shells are exfoliated. The strong ribs generally divide into three, and it is presumed that further divisions take place. The rounded character of the primary plications distinguish it from Spirifer fasciger Keyserling, in which they are angular. It resembles the Mongolian form rather than the Himalayan. According to Diener the form is variable and is also one of the most common fossils of the Productus limestone.

Spiriferella salteri Tschernyschew
mutation ? Grabau

1856-1857. Spirifer artica Haughton, Journal Royal Dublin Society, pp. 210-214, 238-250, Pls. 5-11.

1902. Spiriferella salteri Tschernyschew, Die obercarbonischen Brachiopods d. Ural und d. Timan, Mem. Comité Geol. Vol. 16, No. 2, p. 528, Pl. 12, figs. 5, 6.

1931. Spiriferella salteri Tschernyschew mutation ? Grabau, Permian of Mongolia, pp. 136-138, Pl. 19, figs. 1a-d; Pl. 20, fig 7; Pl. 22, fig. 6.

The resemblance of the specimens from the Cache Creek series to the Mongolian variety is striking, and may safely be ascribed to that variety. There is a slight difference in that the pedicle valve of the Mongolian form is less convex that in our species, but such differences are common in fossils of the same species.

It differs from Spirifer arctica Haughton in that the lateral plications divide into two or three, whereas Haughton mentions six or seven strong plications with one small one between each of the first three adjacent to the median sinus. Haughton's description is meagre, and comparison is based chiefly on the figure accompanying it.

It is probable that the specimens under consideration are the same as those which Girty has reported

as Spirifer cf. artica from several localities in British Columbia and the Yukon. The specimens studied here are probably better preserved than any that have come to his attention.

Subfamily Reticulariinae Waagen
Genus Reticularia McCoy
Subgenus Squamularia Gemmellaro

Reticularia (Squamularia) lineata Tsch. non Martin

1862. Spirifer lineatus Davidson, British Brachiopoda, Vol. 2, pp. 62-66; Pl. 13, figs. 4, 5, 6, 9.
1897. Reticularia lineata Diener, The Permocarboniferous Fauna of Chitichun, Palaeontologica Indica, Series 15, Vol. I, Part 3, pp. 56-59, Pl. 9, figs. 5, 6, 7, 8.
1902. Reticularia lineata Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Mem. Comité Geol. Vol. 16, No. 2, p. 574, Pl. 20, figs. 9-13.

Davidson's specimen from the Carboniferous limestone of England shows a somewhat shallow median sinus while those from the Urals and from British Columbia have none. The specimen from the Urals has about thirty transverse, concentric ridges from beak to anterior margin whereas the British Columbian form shows about twenty-four. Apart from this the two species are identical.

Diener reports a Reticularia lineata from the Himalayas, in which the median sinus is develcped in some specimens, but is only indicated in others.

Daly found fossils in this area in British Columbia, among them being one identified by Girty as Squamularia lineata which is undoubtedly the same as the above.

Family Suessiidae Waagen
Genus Spiriferina

Spiriferina billingsi Shumard

1860. Spiriferina billingsi Shumard, Trans. Acad. Sci. St. Louis, Vol. 1, p. 294.
1884. Spiriferina ornata Waagen, Productus Limestone Fossils, Palaeontologica Indica, Series 13, Part 4, (fas. 3), p. 505, Pl. 50, figs. 1, 2.
1902. Spirifer ornatus Tschernyschew, Die obercarbonischen Brachiopoden d. Ural und d. Timan, Mem. Comite Geol., Vol. 16, No. 2, p. 515, Pl. 12 figs. 8, 9, 10; Pl. 37, figs. 8, 9, 10, 11.
1908. Spiriferina billingsi Girty, Guadalupian Fauna, U. S. G. S. Prof. Paper 58, pp. 374-376, figs. 16-19d.

This species is considered as identical with that described by Shumard and Girty from the middle of the Permian Capitan limestone of the Gaudalupe mountains of Texas. The specimen from the Cache Creek series has seven imbricating lamellae to 5 mm. in the median sinus, which is the minimum number allowed by Girty.

It differs from Spiriferina ornata Waagen of the Salt Range and of the Urals in having a better developed sinus with the lateral radial striae correspondingly smaller. The striae are five in number, whereas Spiriferina ornata has four.

Phylum MOLLUSCA
Class PELECYPODA Goldfuss
Order Prionodesmacea Dall
Superfamily Pectinacea Reeve
Family Pectinidae Lamarch
Genus Aviculipecten McCoy

Aviculipecten laqueatus Girty

1908. Aviculipecten laqueatus Girty, Guadalupian Fauna, U. S. G. S. Prof. Paper 58, p. 439, Pl. 9., fig. 11.

As the ears of the specimens from the Cache Creek series are lacking, accurate and definite comparison cannot be made. The surface ornamentation of the species, which is formed by radiating and concentric ribs, suggests Girty's species from the middle of the Capitan limestone.

The following table gives a list of the fossils with the occurrence of the species in the Capitan limestone, Schwagerina Kalk, Jisu Honguer limestone, Basleo beds and the Productus limestone:

PARTIAL LIST OF THE FAUNA OF THE C[illegible]

Species	[illegible]	Chaetopoda, Crustacea, Mollusca	Tissue Nematoda, Trematoda, Cestoda	Phylum Nematoda, Class Adenophorea	Phylum Nematoda, Class Secernentea
Nassarius peruvianus (Dunker)					
Waregoonyllum columbianum Smith					X
Terebasella heterochaeta (Potts)				X	
Tetrastemma [illegible] (Dabbi)				X	
Ferenema [illegible] (Basel-)				X	
Polycera [illegible] (Pallas)				X	
Calyptraea [illegible] (Conrad)					X
Polycera [illegible] (Kelaart)					X
Phyllaplysia [illegible] (Pruvot)					X
Thalassema [illegible] (Ehlers)		X	X		X
Cerebratulus [illegible] (Verrill)		X			X
Cumingotoria [illegible] (Pruvot)		X			
Cerebratulus [illegible] (Verrill)		X			

PARTIAL LIST OF THE FAUNA OF THE [illegible] (continued)

Species	Texas	Schuylerville-Valley, Ohio	Iowa Wanderer Fs., Montpelier	Rosiclare Fs., Tinnor	Brassfield Fs., Cin. Range
Camarophoria mutabilis Tsch.[2]		X	X		
Camarophoria cf. plicata Tsch.[2]		X			
Spirifer interplicatus Rotai. var. obscurica Tsch.[2]		X			
Spirifer modestus Hall.			X		X
Spiriferella saffordi Tsch. [illegible][2] [illegible]			X		
Squamularia (Reticularia) [illegible] Tsch. non Marcou		X			X
Spiriferina billingsi Shumard[2]	X				
Aviculipecten cf. laqueatus Girty[2]	X				
Propinnacocerus americanum Miller and Wagner	related to Propinnacocerus heyseli of the Rosiclare of Illinois.				

[1] Collected by the writers.

[2] Identified by the writers.

The preceding table shows decidedly a Russian and Himalayan facies, and a less decided though definite relation to the Mongolian fauna through Spirifer moosakhailensis and Spiriferella salteri mutation?. The presence of Propinacoceras americanum definitely links up the Cache Creek series with the Tethys, the genus Propinacoceras being reported from Sicily, the Urals, Croatia, Crimea and Timor. The Bryozoa, Fenestella basleoensis, F. parviuscula, F. cf. pulchradoralis and Polypora megastoma, which are found on Vancouver island and Timor correlate the Basleo beds of Timor with the Cache Creek series. Neoschwagerina is an Oriental form. The relationship with the Texas Permian is very slight, and it is worthy of note that no resemblance has been established with the fauna of the Permian Phosphoria formation of Wyoming and adjacent states. The fauna of the Cache Creek series, therefore, shows affinities with the European and Asiatic Tethys, but very little, if any, with the other Permian faunas of North America.

CHAPTER IV

ECONOMIC GEOLOGY

Mineralization has taken place chiefly in the quartzite and serpentines of this series. Only in one place was the limestone observed to be mineralized, and there it carried small crystals of pyrite.

GOLD

Placer Deposits. Gold can be found in practically any stream in British Columbia, but the amount contributed by the Cache Creek series appears to be small. Drysdale[24] and Dawson have suggested that part of the gold of the Fraser river has been derived from the quartzites of this series. McCann[25] states that an analysis of the quartzites of the Bridge River series (= Cache Creek) at Bridge river yielded a trace of gold, and that this series may be a source of the placer gold found there.

[24] Drysdale, C. W., Western Part of the Belt of the Interior Plateaus: Geol. Surv., Can., Guide Book No. 8, p. 240.

[25] McCann, W. S., Geology and Mineral Deposits of the Bridge River Map-area, B. C.: Geol. Surv., Can., Mem. 130, p. 69.

Clapp[26] attributes the source of the placer gold of

[26] Clapp, C. H., Southern Vancouver Island, Geol. Surv., Can., Mem. 13, p. 154.
Clapp, C. H., Sooke and Duncan Map-areas, Vancouver Island: Geol. Surv., Can., Mem. 96, pp. 367-368.

South Vancouver island to the Leech river series (= lower part of the Cache Creek series) as the auriferous deposits are found only where the streams flow through these rocks.

In other placer regions such as the Cariboo other rocks have supplied the gold.

Gold-bearing Veins. This series does not seem to support hard-rock mining to any extent. The Big Slide Mine[27]

[27] Dawson, G. M., Kamloops Map-sheet, British Columbia: Geol. Surv., Can., Annual Report 1896, pt. B, pp. 339-340.

at the junction of Kelley creek and the Fraser river is located in the quartzites, and was operated for a time. A certain amount of prospecting has been done, but development hardly proceeded beyond that stage. It is interesting to note that on account of the present high price of gold many of these prospects are being re-examined at the present time.

In the Coquihalla district[28] considerable pro-

[28] Cairnes, C. E., The Serpentine Belt of the Coquihalla Region, Yale District, B. C: Sum. Rept. 1929A, pp. 196-197.

specting has been done in the serpentines, and although free gold has been found at a great number of places, only on one property was it sufficiently concentrated to warrant development.

In general it appears that the mineralized quartz veins of this series are too small and erratic to be worked.

ASBESTOS

Small seams of chrysotile or serpentine asbestos have been found in the serpentine rocks in the region of Cache creek and Bridge river, but to date no workable seams have been discovered. The fibre in thin seams is too short to be of economic value. According to Dawson possibilities are fairly good for the discovery of workable deposits in this area.

STRUCTURAL MATERIALS AND ORNAMENTAL STONES

Marble. This rock is too much fractured and jointed to admit of use.

Serpentine. The above statement, concerning marble can also be applied to this rock.

LIME

Limestone is abundant but contains too many small quartz veins, and also chert in many places, to be of much

value. A number of attempts has been made to burn this limestone but, as far as is known to the writer, they never got beyond the experimental stage, or after hand-sorting it was burned for private use.

CHAPTER V

SUMMARY

AGE AND CORRELATION

The presence of Leptodus cf. tenuis and Waagenophyllum columbicum gives a definite Permian age to the Cache Creek series. The presence of Propinacoceras americanum fixes the age as Middle Permian, and correlates it with the Sosio beds of Sicily. This makes it the time equivalent of the Word formation of Texas, the Basleo beds of Timor, the Productus limestone of the Himalayas, the Jisu Honguer limestone of Mongolia, the Kungur of the Urals and the Rotliegende of Germany.

As noted previously, the Brachiopod fauna shows greatest affinities with the Schwagerina-Kalk of the Urals, which Schuchert places at the base of the Lower Permian; the writer places the Cache Creek series higher up in the Permian as some of the characteristic forms, Spirifer interplicatus var. basckirica and Spirifer salteri mutation? show a slightly further development than the typical Schwagerina-Kalk fauna.

The Cache Creek series is the only known representative of the Palaeozoic Era in the interior of British Columbia.

UPPER AND LOWER LIMITS OF THE SERIES

The uppermost rocks of the Cache Creek series have been shown to be Middle Permian in age as that is the highest horizon in the widely separated areas of Kamloops, Marble canyon and Buttle lake of Vancouver island. Also, as the series is best developed in the Marble canyon and Kamloops areas, it is hardly probable that higher horizons could be expected elsewhere.

According to Dawson the lower limit of the series may extend into the Devonian. He based his conclusion on the fact that in the Rockies the Devonian passes into the Carboniferous with no distinct break. However, as it is now known that the Cache Creek series is of Permian age, and was laid down by a different sea which did not progress east of the Selkirk mountains, there is no good reason for adhering to this view, especially as there is no evidence of the Devonian where the Cache Creek rocks are found. The bottom of the series is exposed only in the Ketchikan area and in the Yukon. The fauna of these regions has been stated to be Gschelian in aspect, but it has been shown by the writer to be related to the fauna of the Cache Creek series, which is Permian in age. Therefore it would seem that the lowermost rocks of the series fall within the Permian, and that

the whole of the Cache Creek series is Permian in age.

DISTRIBUTION OF LAND AND SEA IN PERMIAN TIME

The sedimentary rocks of the Cache Creek series were laid down by a Permian sea, which covered an area

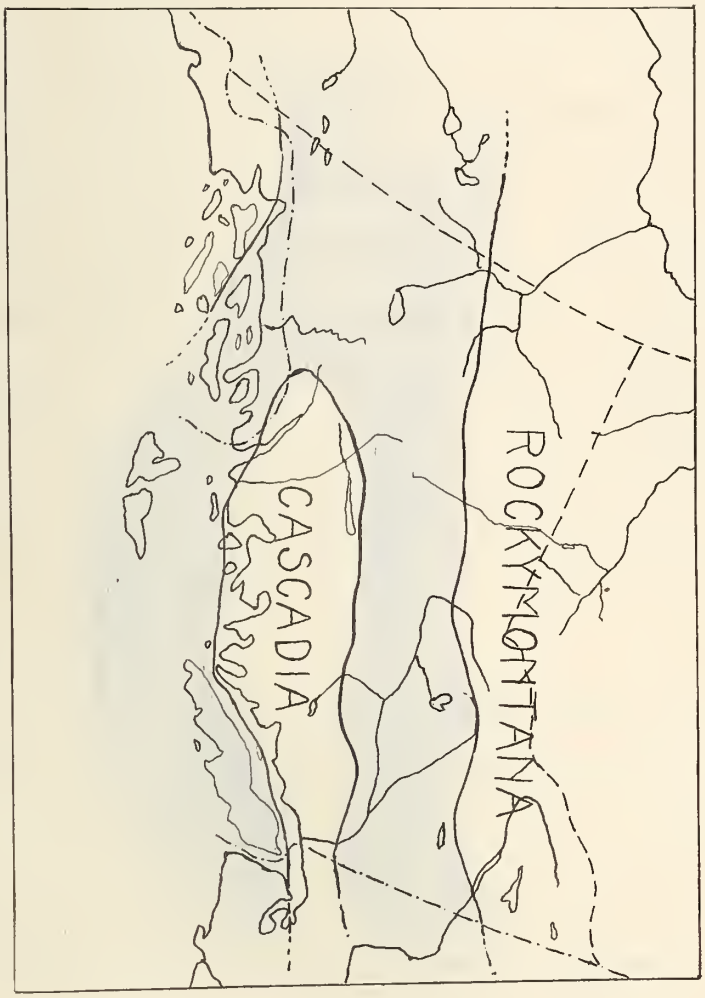

FIG. 2.--Palaeogeographic map of British Columbia, showing the probable distribution of land and water (blue) in Permian time. (Modified from Grabau, Textbook of Geology, Part 2.)

from eastern Europe and Asia over Alaska and the Yukon into British Columbia. According to our present knowledge of the distribution of the series in northern British Columbia the sea was divided by a high land. This land is known as Cascadia. One arm of this sea extended in a westerly direction and connected with the Pacific ocean. The other arm extended southward down the centre of the province into Washington, and occupied a geosyncline, which was roughly parallel to the present shoreline of the Pacific. This geosyncline extended from the Shuswap lakes on the east to the lower Fraser valley on the west. It appears that it was not connected with the Permian seas of Texas or Wyoming and adjacent states.

At the same time a Pacific overlap covered Vancouver island.

The land mass of Cascadia comprised the present Coast and Cascade ranges of British Columbia. In the eastern part of the province there was a high land called Rockymontana. This high land comprised the present Columbia, Selkirk and Purcell mountain systems.

Y U K O N
P A C I F I C O C E A N
Stikine R.
Dease R.
Liard R.
Black River
Fort Nelson R.
Hay Lake
Hay River
Finlay R.
Finlay River
Ingenika R.
Ingenika R.
Omineca R.
Parsnip R.
Peace River
Fort St. John
Pine River
Pine River
Smoky River
Sikanni Chief R.
Halfway R.
Beatton R.
Beatton River
Kiwigana R.
Muskwa R.
Fort Nelson
Fort Liard
Fort Simpson
Fort Wrigley
Fort Norman
Fort Good Hope
Arctic Red R.
Mackenzie R.
Great Bear Lake
Great Slave Lake
Hay River
Fort Resolution
Fort Smith
Fort Providence
Fort Rae
Yellowknife
Reliance
Aklavik
Inuvik
Tuktoyaktuk
Coppermine
Cambridge Bay
Victoria Island
Banks Island
Prince Patrick Island
Melville Island
Ellesmere Island
Axel Heiberg Island
Devon Island
Baffin Island
Southampton Island
Coats Island
Mansel Island
Akimiski Island
Belcher Islands
Nottingham Island
Resolution Island
Frobisher Bay
Cape Dyer
Cape Chidley
Port Burwell
Lake Harbour
Cape Dorset
Pangnirtung
Broughton Island
Pond Inlet
Arctic Bay
Resolute
Grise Fiord
Eureka
Alert
Craig Harbour
Lake Harbour
Port Burwell
Cape Chidley
Cape Dyer
Frobisher Bay
Broughton Island
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Cape Dorset
Pangnirtung
Broughton Island
Pond Inlet
Arctic Bay
Resolute
Grise Fiord
Eureka
Alert
Craig Harbour
Whitehorse
Atlin
Atlin Lake
Tagish Lake
Tahltan Lake
Dease Lake
Telegraph Creek
Stikine R.
Tahltan R.
Tahltan River
Jennings River
Jennings R.
Liard R.
Black River
Fort Nelson R.
Hay Lake
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Ingenika R.
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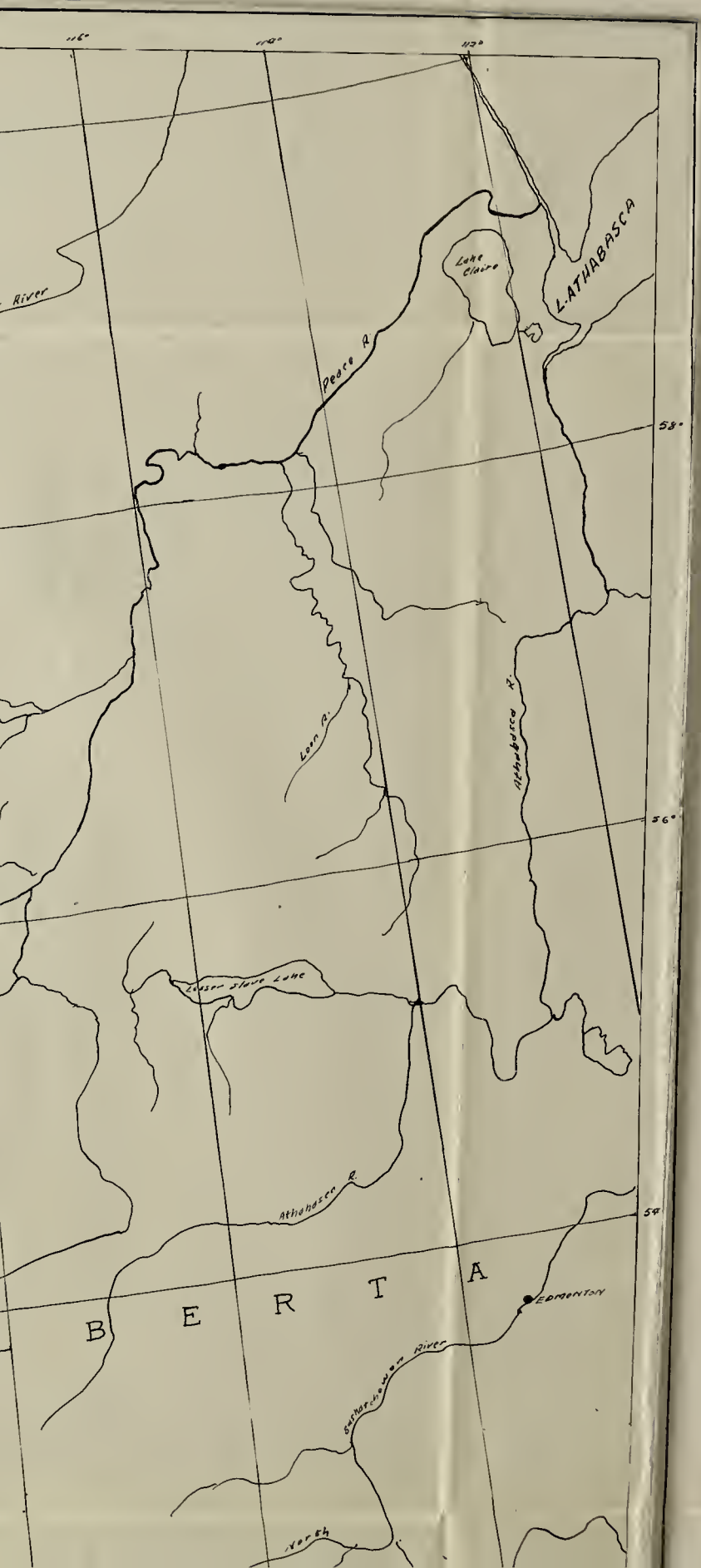
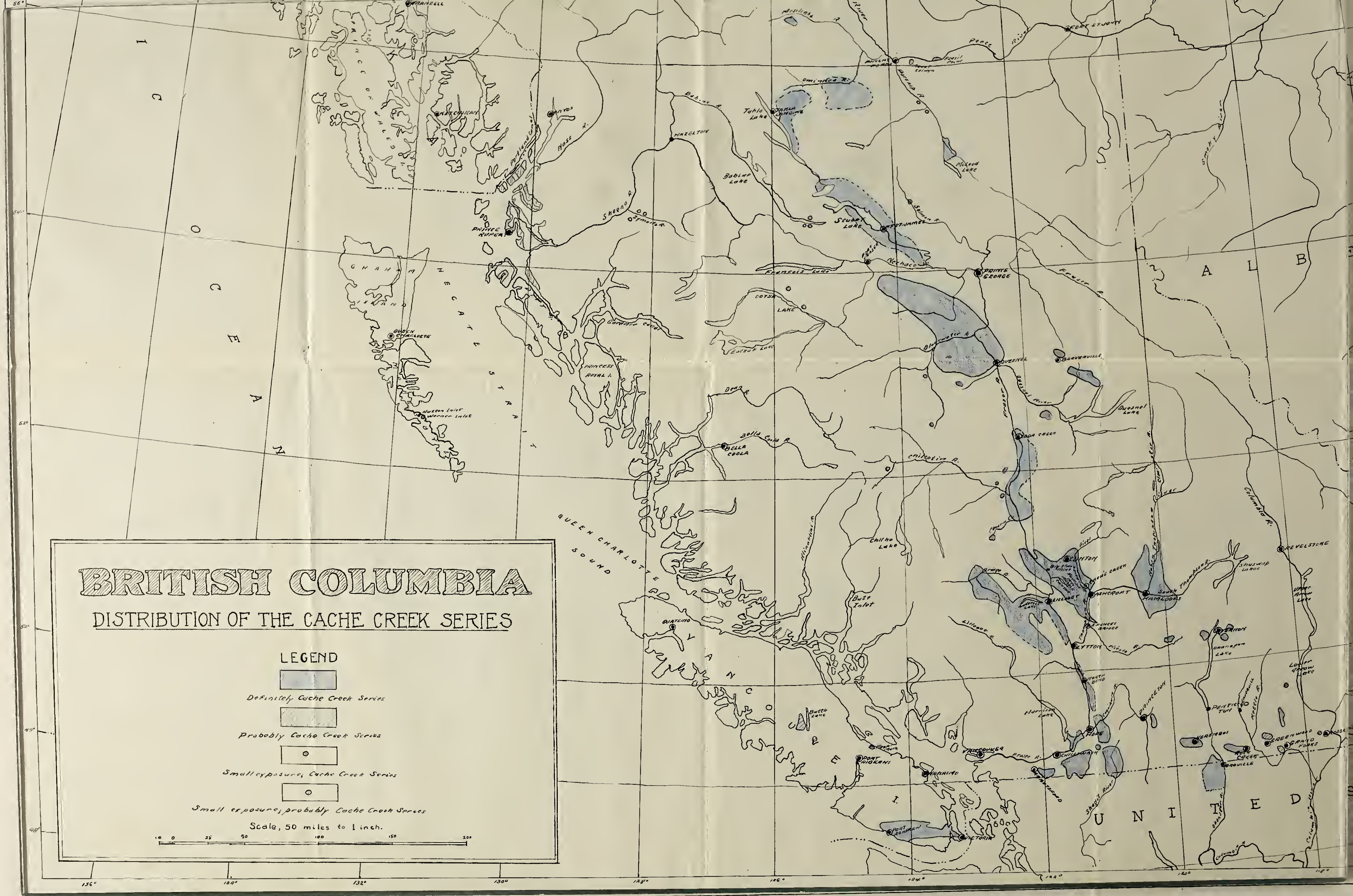

116°
114°
112°
Peace R
Lake Claire
L. ATHABASCA
58°
Loon R.
Athabasca R.
56°
Lesser Slave Lake
Athabasca R.
54°
B E R T A
EDMONTON
SASKATCHEWAN River
North



BRITISH COLUMBIA
DISTRIBUTION OF THE CACHE CREEK SERIES
LEGEND
Definitely Cache Creek Series
Probably Cache Creek Series
Small exposure; Cache Creek Series
Small exposure; probably Cache Creek Series
Scale, 50 miles to 1 inch.
10 0 25 50 100 150 200
136° 134° 132° 130° 128° 126° 124° 122° 120° 118°
56° 52° 50° 49° 48°
I C O C E A N
HECATE STRAIT
QUEEN CHARLOTTE SOUND
VANCOUVER I.
A L B
U N I T E D
GRAHAM ISLAND
QUEEN CHARLOTTE
PRINCESS ROYAL I.
PRINCE RUPERT
KETCHIKAN
HAZELTON
Babine R.
Babine Lake
Skeena R.
Zymoetz R.
Nass R.
Portland Canal
Tahla Lake
TAKLA LANDING
Mesilinka R.
Omineca R.
FINLAY FORKS
Parsnip R.
Peace River
FORT ST.JOHN
Fossil Point
McLeod Lake
Salmon R.
Smoky River
Stuart Lake
FT. ST. JAMES
FORT FRASER
Nechaco R.
Francois Lake
DOTSA LAKE
Eutsuk Lake
Gardner Canal
PRINCE GEORGE
Fraser R.
Blackwater R.
QUESNEL
BARKERVILLE
Quesnel River
Quesnel Lake
SODA CREEK
Chilcotin R.
Dean R.
Bella Coola R.
BELLA COOLA
Chilko Lake
Bute Inlet
QUATSINO
Buttle Lake
PORT ALBERNI
NANAIMO
VANCOUVER
Fraser R.
CHILLIWACK
PORT RENFREW
VICTORIA
Columbia R.
REVELSTONE
Shuswap Lake
South Thompson R.
North Thompson R.
KAMLOOPS
ASHCROFT
LILLOOET
LYTTON
Nicola R.
SPENCES BRIDGE
Bridge R.
Lillooet R.
NORTH BEND
Harrison Lake
HOPE
PRINCETON
VERNON
Okanagan Lake
PENTICTON
KEREMEOS
Kettle R.
ROCK CREEK
OROVILLE
GREENWOOD
GRAND FORKS
Upper Arrow Lake
Lower Arrow Lake
Skagit River
Okanagan R.

M.B.B.Crock

FIGURE 1

M.B.B. Crockford

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